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ULTIMATE TROUGH® - Fabrication, erection and commissioning of the world's largest parabolic trough collector

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Abstract

A first Ultimate Trough® (UT) collector demonstration loop was successfully integrated in an existing solar power plant in California and is now put into operation. Its huge dimensions of one Solar Collector Assembly (SCA) with an aperture of 7.5 m and a length of 247 m makes it the largest parabolic trough collector ever built and operated. It is expected that this collector reduces the solar field cost by 20 to 25 %.
The fabrication and erection of a collector with the present dimensions exceeds present knowledge and experience. To provide safety for the design of upcoming solar thermal power plants with the same collector, it was decided to demonstrate all fabrication and erection procedures as they will be applied in series production.
The paper describes the part manufacturing, as well as site assembling procedures, transportation and new developed erection tools. Furthermore, it gives an overview on the assembly process on site.
The UT collector is designed to avoid complex and costly SCE alignment procedures in the field. The principles and results of the new SCE alignment method are presented.
With this new parabolic trough collector a major step towards solar field cost reduction has been achieved. The development process has reached the final step, and the Ultimate Trough has reached market maturity. It is now planned to be applied for commercial collector field applications.

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Introduction

CSP and especially the field of PTC urgently requires significant cost reduction steps via technical innovations to remain or regain competitiveness. On the other hand, the financing sector demands mature, approved systems to judge the technology as bankable. Both of these requirements have to be considered in parallel although they contradict each other in some respect.

Therefore, innovation steps have to be carefully planned, tested and demonstrated but also kept on a fast track. To cope with these requirements, FLABEG, schlaich bergermann und partner and further partners have set-up the development of a new PTC, the Ultimate Trough, within a period of 2 ½ years in systematic steps, as they were approved successfully in former development programs like with the ET:

1. Design phase
2. Prototype collector
3. Test loop integrated in a commercial plant
4. Commercial application

The development of the UT has recently completed step 3 in the list above. Within these steps, the UT has made some significant technological steps which are described in the following Chapters. More than doubling its size compared to state of the art collectors, and thus being the largest PTC ever built and operated, is one of these innovations.

At this stage of development, the behavior of the system is checked and reported as an input for e.g. a risk analysis before using this technology in a commercial application. Additionally, the performance has to be evaluated and reported. First results of the performance are given in [1].

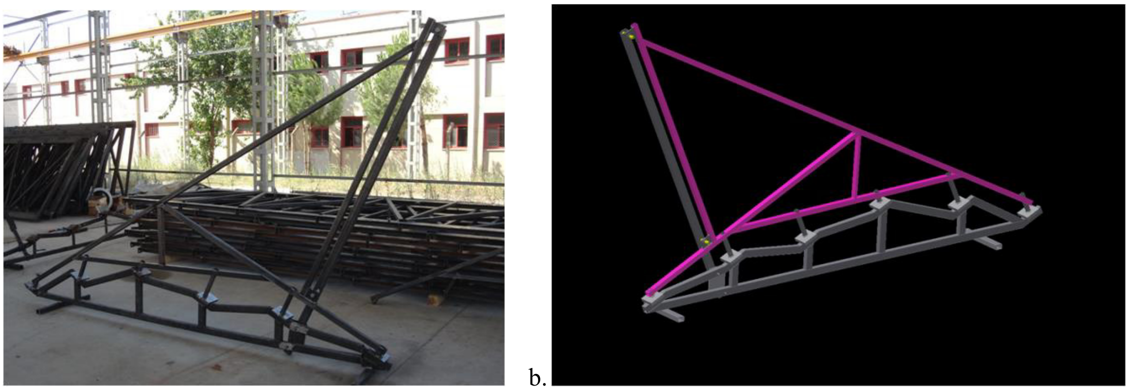
Nomenclature

PTC	Parabolic Trough Collector
UT	Ultimate Trough®
ET	EuroTrough
SCE	Solar Collector Element
SCA	Solar Collector Assembly
HCE	Heat Collecting Element
HTF	Heat Transfer Fluid

1. Fabrication and transportation

1.1. Fabrication methods

Although the number of fabricated parts for the test loop did not justify the application of mass production methods, all parts were manufactured in fabrication jigs as close as possible to series production jigs in order to demonstrate achievable tolerances and required qualities. Quality control methods were also formalized and adapted to series production using checking templates and go-no-go gages. For example, Figure 1 shows the cantilever arm framework part which supports the parabolic mirror panels in the respective go-no-go gage. The jig allows checking of tolerances in the 1 mm range with the lowest amount of required time.

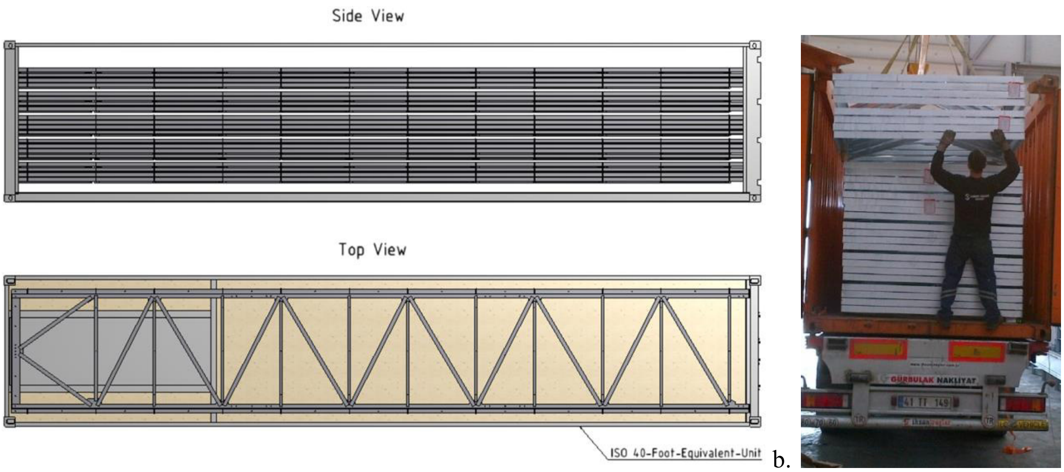


a. b.

Figure 1. Cantilever arm in go-no-go checking jig: a. checking jig in use; b. design of checking jig (cantilever arm in pink)

1.2. Transportation

Due to the upscaling of the SCE to a length of more than 24 m several logistic and transportation issues had to be reconsidered. In order not to restrict the procurement of steel components to local suppliers, a design was chosen which allows overseas transportation of components in 40' open top high cube containers. Transportation in containers leads to significant costs in general. Therefore, the design was optimized to utilize the capacity of standard containers to the highest degree. Figure 2 shows an exemplary container loading layout and the respective execution in the galvanizing plant during fabrication of the test loop.



a. b.

Figure 2. UT design optimized for maximum container capacity utilization: a. exemplary container packing layout; b. filling of container after galvanization

1.3. Raw material selection

The design of the steel structure of the Ultimate Trough is based on the use of commonly available raw material to facilitate fabrication. In particular, steel as construction material with mainly standard section profiles available in most parts of the world is applied in the design. The partitions of applied steel sections in the UT design is represented in Figure 3.

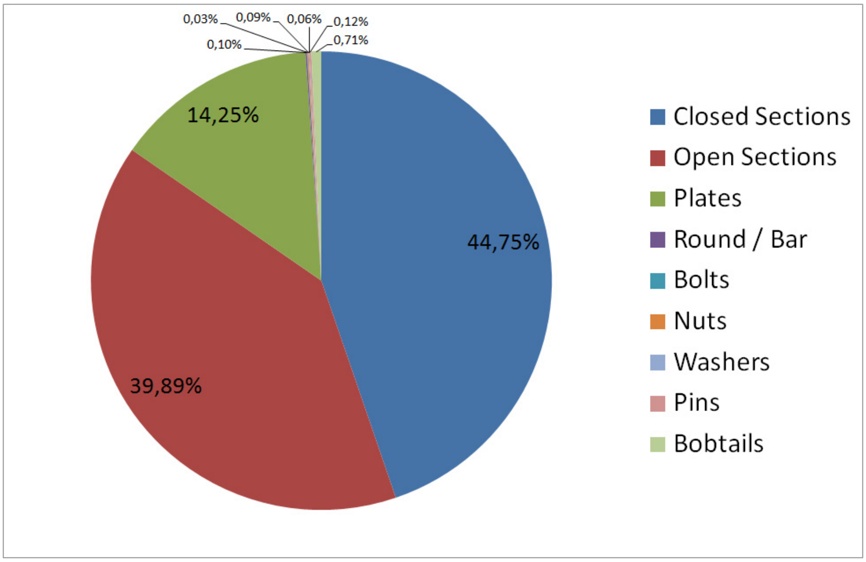


Figure 3. Partition of raw materials for an UT solar field

Closed sections like rectangular hollow sections and open sections like L-profiles dominate and are almost equally distributed.

2. Assembly and erection

All parts were delivered to the collector field in which the UT test loop was going to be integrated. The assembly is based on high precision jigs. The jigs allow the production of high precision collector elements made out of medium to low precision steel and other components. Tolerance deviations of subcomponents are compensated by the jigs. Assembly jigs were set-up in a way that series assembly procedures could be tested. The main deviation from series assembly was that the assembly for the test loop had to take place outdoors. The set-up of the assembly for a solar field is shown in Section 2.4. Figure 4 presents the assembly area used at the test loop site with the three main assembly jigs:

- Box Jig
- SCE Jig
- Mirror Jig

For the test loop a circular set-up was chosen to enable accessing all jigs with one crane placed in the center of the jig arrangement.

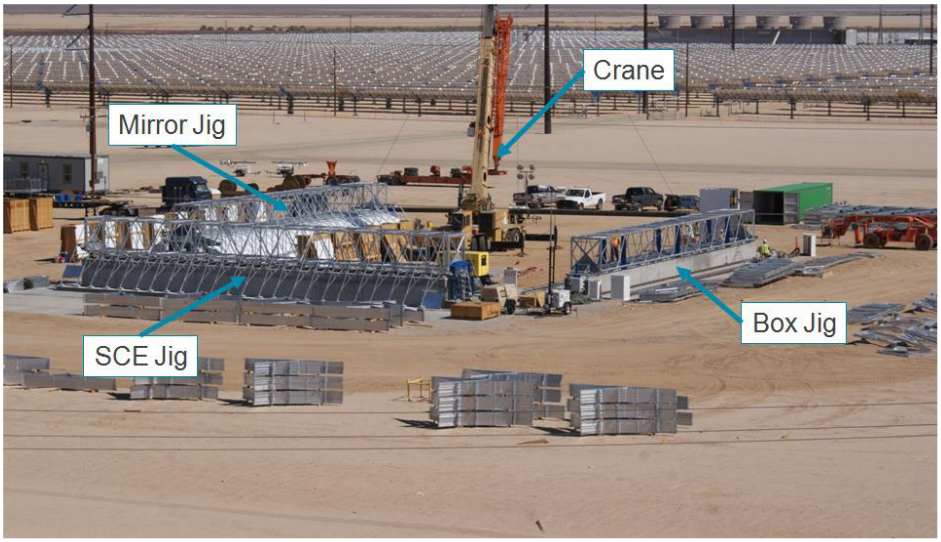
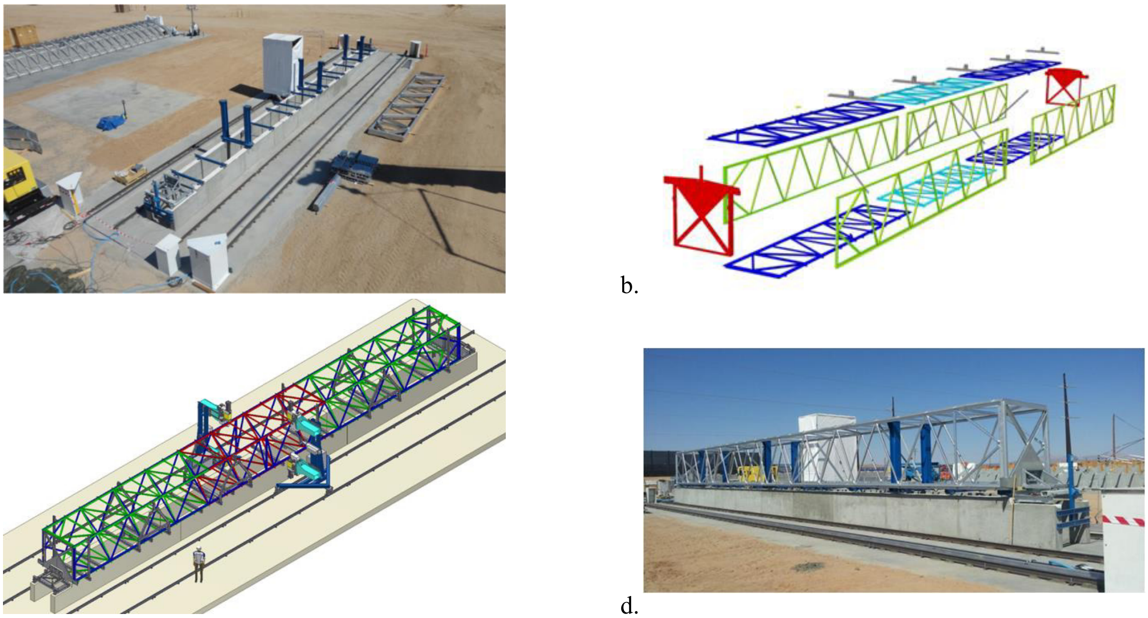


Figure 4. UT test loop area with three main assembly jigs

2.1. Torque Box Jig

The structural body of the structure is formed by a "torque box" made out of two-dimensional framework elements, similar to the Eurotrough [2] collector. The framework elements are assembled in the torque box jig as shown in Figure 5. The jig provides guides to align the members in their correct position.



a. b. c. d.

Figure 5. Assembly process in the Box Jig: a. Box Jig; b. representation of the frame elements to be assembled in the jig; c. clinching tools move along the Box Jig; d. assembled box in the jig

The clinching tool [3] moves fully automated along the Box Jig and joins the frames. Clinching points are distributed along the frame according to the local loads to be transferred within the box framework (300 mm apart from each other on average). The procedure was programmed and executed in a fully automated way as foreseen in the series assembly.

2.2. SCE Jig

The assembled torque box is transferred from the Box Jig to the SCE Jig, where cantilever arms are connected to finally support the 48 mirrors. The cantilever arms are perfectly aligned and positioned on supports of the jig (Figure 6). Tolarances of the individual cantilever arms and the torque box are compensated in lock bolt connections with oversized holes.

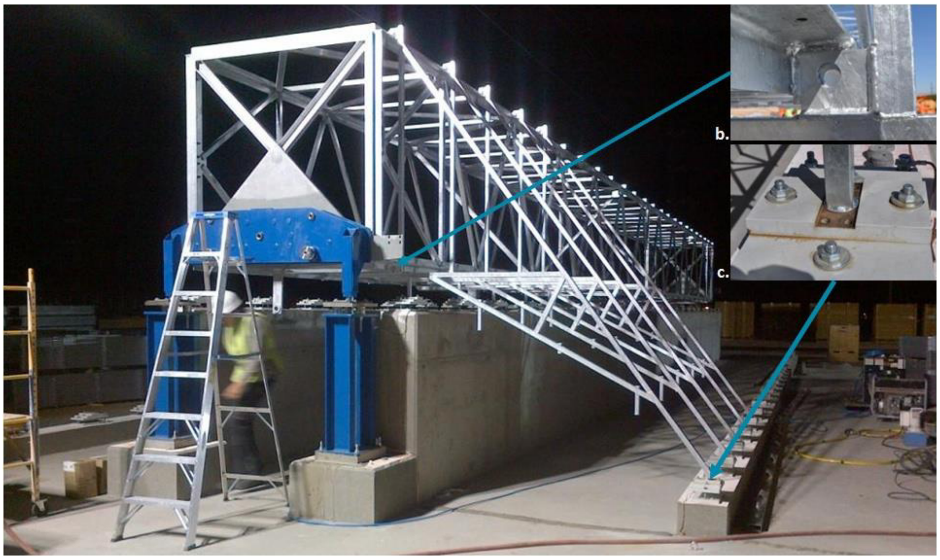
a.


Figure 6. Assembly of cantilever arms in the SCE Jig: a. SCE Jig with assembled box and first cantilever arms in place; b. arm connection in oversized holes; c. support of cantilever arms

2.3. Mirror Jig

The assembly in the Mirror Jig begins with laying out of the mirrors on supports. The supports are laser cut profiles which properly aligned represent the exact parabola shape. This is followed by positioning the steel structure vertically above the jig. The structure is then lowered carefully by a vertical drive unit. As a next step, the joints between the steel support structure and the mirror connection points allowing for three-dimensional tolerance compensation are fixed with a rapid hardening adhesive. Finally, the completely assembled SCE is removed by crane, turned around and placed on the special truck for transport into the field.

Figure 7. Mirror Jig: a. positioning of the steel structure overhead the Mirror Jig; b. removing of the completely assembled SCE; c. rotation of the SCE with a gear motor.

2.4. Collector assembly in series production

The jigs as they are described above will be used in series production more or less identically but in a different set-up. The layout of the assembly line is already designed according to different collector field sizes and different requirements for automizations and fabrication time. An example of a dual assembly line is presented in Figure 8.

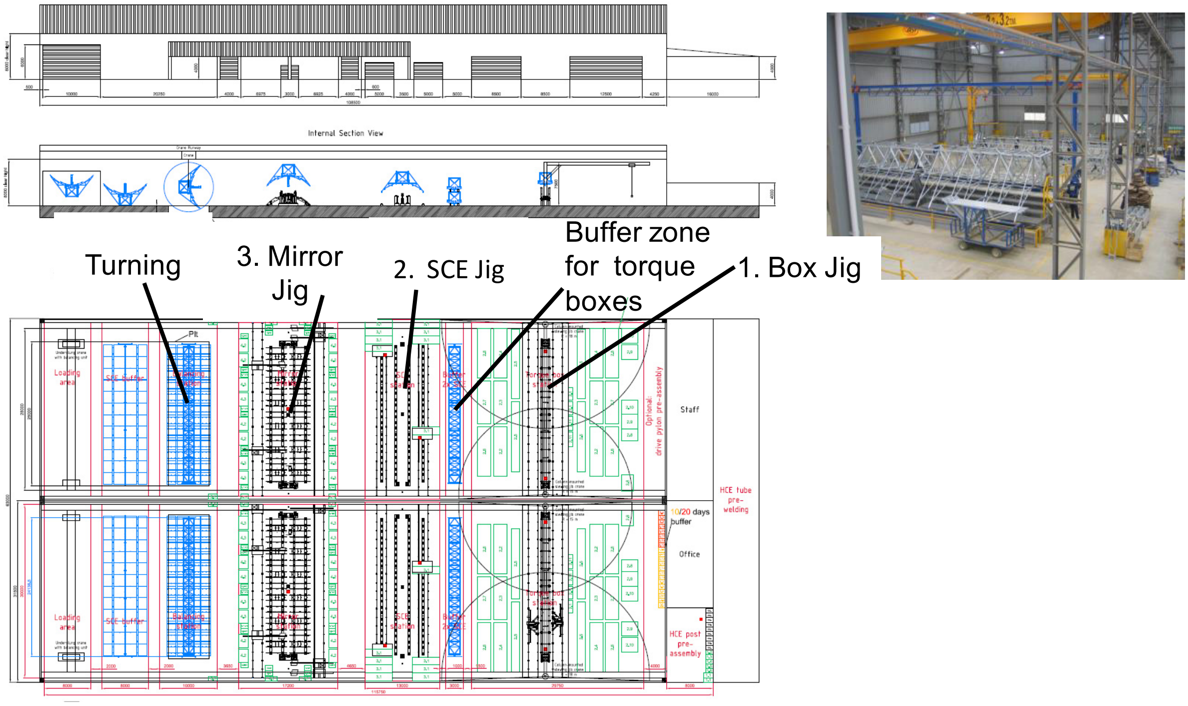


Figure 8. Assembly line as designed with the tested jigs for series production of a commercial plant

3. SCE field assembly and alignment

Transport of the SCE from the assembly area into the field, installation of the SCE on supporting pylons, and alignment of the SCE with already installed SCEs is time-critical for many reasons. Allready assembled SCEs are difficult to store as a buffer due to their vast space requirement and their vulnerability against wind loads if not properly secured. This demands a highly automated and quick field assembly. On the other hand, very high precision is required for the alignment of the SCEs within one SCA. The optical quality of one SCE can only be exploited within the whole SCA if all SCEs are precisely aligned with each other keeping a defined high angular tolerance of e.g. +-0.2 to 0.4 mrad. The contradictional requirements of speed and accuracy were realised with the new patented UT alignment concept.

In the Mirror Jig, where shape and orientation of the parabola are defined, the SCE is furnished with two alignment blocks at both ends of the SCE. These alignment blocks get their position from the Mirror Jig, and are fixed in elongated holes (free of stress) with lockbolts to the structure. The alignment blocks define the angular and vertical position of the SCE when joint to the adjacent SCE or drive pylon in the solar field. With a given accuracy of the jig and the blocks, the angular accuracy is maximized by enlarging the distance between the alignment blocks. For this reason, a pair of blocks is positioned approximately 2,0 m apart from each other at each end of the SCE. Figure 9 represents the installation of the SCE at the drive pylon (SCE-SCE connection is similar). The SCE is simply lowered on the alignment blocks and subsequently fixed with lockbolts to the adjacent SCE or to the drive pylon. No additional adjustment is required in the field as it is required for comparable PTC systems. Remeasurement of the alignment and the measured performance of the SCA at the test loop show that the desired accuracy was reached.

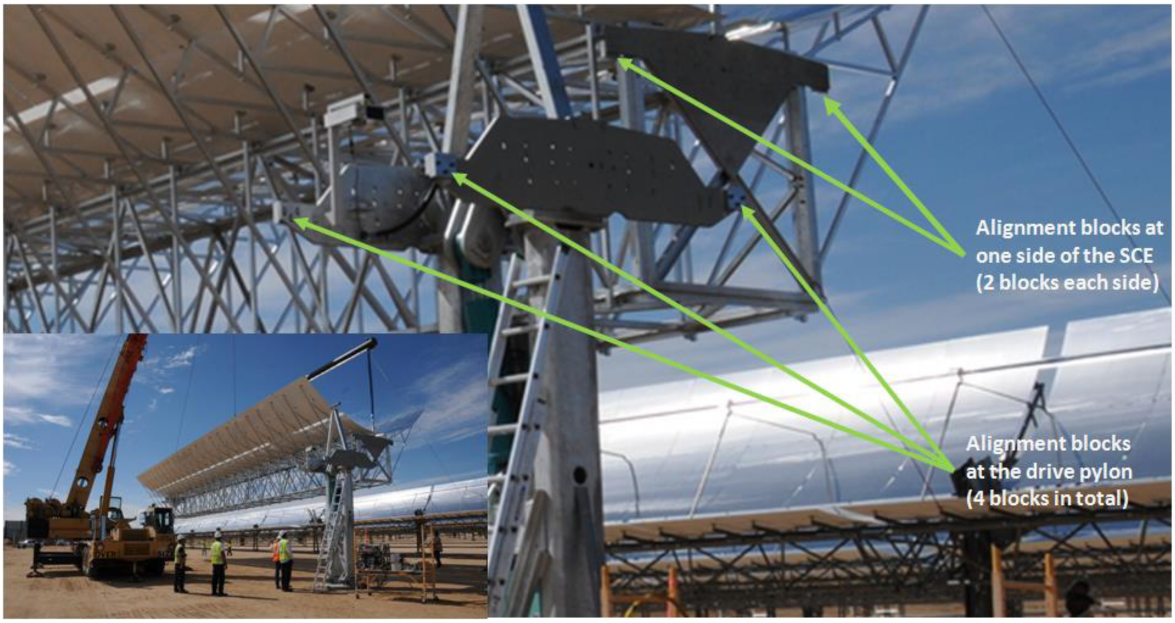


Figure 9. Alignment of the SCE in the field. The SCE is lowered by crane on the alignment blocks

This simplification saves time during installation and provides reproducable accuracy in the field assembly.

4. Project status and technical risk assessment

The development of the Ultimate Trough started in 2010, a prototype was installed and tested in 2011 [3][4] and the test loop was erected in 2012. After commissioning early this year, up to now the test loop has been in continuous operation since approximately half a year. Performance data and operation experience is continuously collected since then. This closely monitored operation will continue for another half year. After this period, the system will continue as an integrated normal part of the existing power plant.

With reaching the end of the described timeline above and the release of a concluding performance report (initial performance reported in [1]), the Ultimate Trough has reached market maturity and is planned to be applied for collector field applications. The successive steps prototype/ test-loop/ market maturity have been conducted already successfully with the Eurotrough [2] and the HelioTrough [5].

A risk assessment for the UT showed that the technical risk for deployment in a commercial powerplant can be considered very low. The low level of technical risks of the UT is mainly explained due to its close technical “relation” to the well approved EuroTrough, but also due to the thorough implementation of all “innovations” for prototype and test loop in the same way as they will be implemented in series production.

Outlook

The development of the UT is completed with regard to the system using oil for the HTF system. A commercial application is the next consequent step. Due to its special qualification for the use with molten salt [6] the next R&D development step will be the demonstration of the UT in a molten salt system.

Acknowledgements

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